Selective patterning of amorphous silicon on MoS_2 to fabricate transition-metal dichalcogenide heterostructures

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Ultrathin transition-metal dichalcogenide (TMD) layers such as MoS_2 and WS_2 are promising materials for 2D heterostructures as building blocks for steep subthreshold-slope devices. Such a heterostructure of those TMDs with their strong interlayer interactions can be used as tunnel field effect transistors (TFET) [1, 2]. Proof-of-concept TFET structures are nowadays based on exfoliated and then stacked flakes, or grown on top of each other by chemical vapor deposition (CVD).

We here propose a novel and innovative approach which converts amorphous Si (aSi) into WS_2 by means of WF_6 and H_2S [3]. The conversion is done at a temperature of 450 °C and yields stoichiometric, but randomly oriented WS_2. Rapid thermal annealing in inert gas at 900 °C crystallizes the layers and yields horizontally aligned WS_2 films. By pre-patterning the aSi films, the desired geometry of WS_2 structures can be achieved. Arrays of WS_2 lines down to 20 nm width can be obtained.

To enable TFET architectures with stacked layers based on this synthesis route, the selective removal of deposited aSi layers on MoS_2 by a low damage etch process is required. To this end, a low power atomic layer etching (ALE) process has been explored, using an Oxford Instruments ICP chamber equipped with an ALE kit to inject short Cl_2 pulses into the process chamber [4]. The cycles consist of four steps, starting with a chlorine exposure, a purge, a biased Ar plasma etching step, and a final purge step. After optimization of the process conditions, this ALE sequence removed aSi while preserving the underlying MoS_2. This achievement could enable TFET fabrication by applying the proposed aSi-to-WS_2 conversion on top of MoS_2. Although a defectivity reduction by appropriate annealing protocols in sulfur-rich environments need to be addressed in the future, the proposed methods open the way to build TFET structures using VLSI-compatible techniques.

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References

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Figures

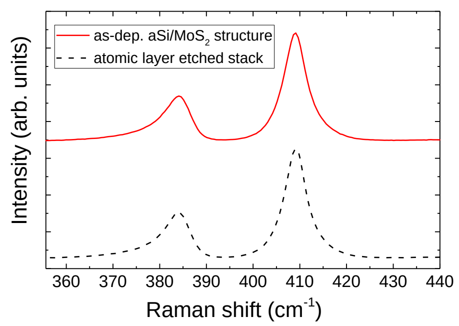

Figure 1: Raman spectra show the preservation of MoS_2 even after atomic layer etching